(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
25 May 2001 (25.05.2001)

PCT

(10) International Publication Number
WO 01/37454 A1

(51) International Patent Classification[7]: H04B 7/26, H04Q 7/38

(21) International Application Number: PCT/SE00/02112

(22) International Filing Date: 27 October 2000 (27.10.2000)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
09/443,311 19 November 1999 (19.11.1999) US

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(81) Designated States (*national*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, UZ, VN, YU, ZA, ZW.

(84) Designated States (*regional*): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published:
— *With international search report.*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

WO 01/37454 A1

(54) Title: FREQUENCY HOPPING IN GPRS/GSM COMPACT COMMUNICATIONS SYSTEM

(57) Abstract: Techniques for performing frequency hopping in a wireless Time Division Multiple Access (TDMA) communications system employing both frequency and time reuse permit frequency hopping on every timeslot in the system, and therefore permit successful frequency hopping even for multislot allocations to a single mobile station. An exemplary method includes the steps of allocating a first type of logical channel to a single frequency on a shared time slot, and allocating a second type of logical channel to a frequency hopping sequence including at least two frequencies on the same shared time slot.

FREQUENCY HOPPING IN GPRS/GSM COMPACT COMMUNICATIONS SYSTEMS

Field of the Invention

The present invention relates generally to wireless communications and, more particulary, to frequency hopping in wireless Time Division Multiple Access (TDMA) communications systems.

Background of the Invention

Recently, there has been a trend in the telecommunication community to focus more and more on wireless packet data communication rather than circuit switched voice communication. With the tremendous increase of Internet users, it is believed that packet switched communication will soon increase further and become larger than the circuit switched voice communication that today dominates, e.g., cellular communication. Cellular communication system manufacturers and operators are therefore looking for solutions to integrate circuit switched services with wireless packet switched services that can provide reliable and more spectrum efficient connections for packet switched users, e.g., Internet users. This trend has made different types of packet switched communication system evolutions flourish. One of the more well known packet switched cellular systems in the telecommunications community is the extension of the present Global System for Mobile Communication (GSM), known as General Packet Radio Service (GPRS).

GPRS is a packet switched system that uses the same physical carrier structure as the present GSM cellular communication system and is designed to coexist and provide the same coverage as GSM. The GPRS radio interface is thus based on a Time Division Multiple Access (TDMA) structured system with 200 kHz carriers divided into eight timeslots with Gaussian Minimum Shift Keying

(GMSK) modulation. The multiplexing is such that each timeslot can typically serve a number of users. One user can also be allocated more than one timeslot to increase its throughput of data over the air. This is known as multislot allocation. The GPRS specification includes a number of different coding schemes to be used dependent on the quality of the radio carrier. With GPRS, data rates well over 100 kbps are possible.

There is also ongoing development and standardization of a new air interface mode in GSM which will affect both packet and circuit switched modes. This new air interface mode is known as Enhanced Data rates for Global Evolution (EDGE). The main features of EDGE are new modulation and coding schemes for both packet switched and circuit switched data communication. In addition to the GMSK modulation, which today is used in both GPRS and GSM circuit switched mode, an 8-symbol Phase Shift Keying (8PSK) modulation is introduced. Such 8PSK modulation can provide users with higher bit rates than GMSK in good radio environments.

A new technique known as link quality control is introduced with EDGE. Link quality control is a functionality that allows adaptation in terms of coding and modulation with respect to present signal quality. In poor radio conditions, a robust coding and GMSK modulation is selected, whereas in good radio conditions a less robust coding and 8PSK modulation is used. GPRS, and the extensions thereof, also include a backward error correction functionality in that retransmissions of erroneously received blocks can be requested (in this regard, note that one block is herein used as the smallest entity for which a retransmission can occur; a block is formed of, dependent of the modulation and coding scheme used, two or four consecutive GSM frames on one timeslot). This retransmission mechanism is referred to as Automatic Repeat reQuest (ARQ) and is a well known mechanism in the art. The EDGE ARQ scheme for packet data is known as Hybrid II ARQ and is more sophisticated than that used for GPRS.

The packet data mode with EDGE modulation is known as Enhanced GPRS (EGPRS), and the circuit switched data mode is known as Enhanced Circuit Switched Data (ECSD). With EGPRS, bitrates over 384 kbps are possible.

Recent development for another TDMA based cellular system (i.e., the cellular communication system compliant to the ANSI/136 standard, below referred to as TDMA/136) has been focused on a packet data system to be integrated with the TDMA/136 circuit switched mode.

This packet data system is also based on the new EDGE technology as defined for the GPRS extension. It thus allows TDMA/136 operators to provide bit rates up to 384 kbps on 200 kHz carriers with GMSK and 8PSK modulation as defined for EGPRS.

This integration of TDMA/136 and EDGE, does not, however, come without a cost. The TDMA/136 carriers have a bandwidth of only 30 kHz, to be compared with the EDGE carriers of 200 kHz. This means that operators that want to introduce EDGE must allocate 200 kHz for each EDGE carrier or, to put it another way, must free up spectrum for each EDGE carrier corresponding to 7 already existing 30 kHz carriers. Since operators already today are using these 30 kHz carriers for circuit switched communications, there is a large interest that the initial deployment for EDGE in TDMA/136 systems should be made on as small a spectrum as possible.

In this regard, note that reuse patterns are used in cellular systems, such that one can reuse the same frequencies in different cells. Systems are usually planned such that a number of cells share a number of available frequencies. For example, in a 4/12 frequency reuse, there are 12 different cells that share a set of frequencies. Within these 12 cells, no frequency is used in more than one cell simultaneously. (The number 4 in "4/12" denotes the number of base station sites involved in the 12 reuse. The 4/12 denotation thus indicates that a base station site

serves 3 cells.) These 12 cells then form what is referred to as a cluster. Clusters are then repeated to provide coverage throughout a certain area.

Similarly, in a 1/3 reuse, there are 3 different cells that share a set of frequencies. Within these 3 cells, no frequency is used in more than one cell simultaneously. The higher the reuse, the better the carrier to interference ratio for an exemplary condition. For lower reuse patterns, the carrier to interference ratio is lower, since the distance between two base stations transmitting on the same frequency is shorter. An exemplary 1/3 reuse is illustrated in figure 1.

GPRS logical channels typically have different levels of robustness depending on the type of logical channel being transmitted. A logical channel is defined by its information content and is transmitted on one or several physical channels, defined by the physical channel structure (e.g., a timeslot on a certain frequency or sequence of frequencies). Examples of logical channels are Packet Data Traffic Channels (PDTCH), Packet Associated Control Channel (PACCH), Packet Random Access Channels (PRACH), Packet Paging Channels (PPCH), Packet Broadcast Channels (PBCCH), Packet Access Grant Channels (PAGCH), etc. A common name for the logical channels PAGCH, PPCH and PRACH is Packet Common Control Channels (PCCCH). Corresponding channels exist for all the GSM based modes, e.g., Circuit Switched, Packet Switched (GPRS), as well as in the Compact mode.

In a packet data system, reliance on retransmission possibilities for user data can allow a quite high error rate, which means that the reuse for user data traffic channels can be kept quite low. For example, a data traffic channel can be deployed in a 1/3 reuse. For the common control and broadcast channels, however, it is desired that these are correctly received at once, and thus a higher reuse is advantageous for these transmissions. At least a 3/9, or even a 4/12, reuse is recommended for packet broadcast and common control channels.

However, a 3/9 reuse entails that at least nine 200 kHz carriers are needed (i.e., TDMA operators must provide at least 1.8 MHZ of spectrum for an initial deployment). This can be prohibitive in a TDMA system with 30 kHz carriers. The Universal Wireless Communications Consortium (UWCC) has required that packet data systems for TDMA/136 use no more than 1 MHz bandwidth.

This fact has driven the TDMA community to find other solutions for initial deployment of a packet data system based on EDGE and GPRS. US Patent Application No 09/263,950, "High Speed Data Communication System and Method", to Mazur et al, hereby incorporated by reference, teaches a method of combining TDMA/136 and the EGPRS mode of EDGE.

Briefly, the solution is to put requirements on the base station transmissions of the EDGE carriers. Base station transmissions of EDGE carriers should be time synchronised. It is then possible to allocate the control channels on different frequencies and different timeslots in different cells to thereby construct a higher reuse than what is possible by only considering frequencies. This solution is often referred to as EDGE Compact, or simply Compact.

In addition to the frequency reuse, a time reuse is introduced. For example, a certain base station transmits control signalling on a certain timeslot at a certain time and on a certain frequency, at which no other base station in the same control channel cluster (i.e., all cells where each physical channel carrying control signaling is used once and only once) is transmitting anything at all. This is repeated between a number of base stations, such that different time groups are formed. Further, to increase reliability of control channel detection in the mobile stations and base stations respectively, timeslots adjacent to each other do not both carry control channel information.

Compact provides the opportunity to introduce a higher reuse than that allowed by frequency repetition only. Thus, it is possible to allow an initial deployment of a GPRS/EGPRS packet data system within a spectrum bandwidth

much smaller than that otherwise limited by the reuse requirement for the control channels. Figure 3A depicts a typical allocation for the control channels as distributed over a multi-frame structure comprising 52 GSM frames. Therein, four different time groups are illustrated on a single frequency (i.e., a 4 reuse in the time domain is formed).

In one cell, control information is transmitted in timeslot 1, (TS 1), i.e.,timegroup 1 (TG1), in certain GSM frames defined. Base stations transmitting control information on the same frequency, but belonging to another time group, will not transmit at all during the frames that are used for control in base stations belonging to TG1. In another cell, control information is transmitted in TS3 (i.e., TG2), again in certain GSM frames. Base stations transmitting control information on the same frequency but belong to another time group, will not transmit at all during the frames that are used for control in base stations belonging to time group 2. Similar reasoning applies for TS5 and TS7.

Combining the time reuse with, e.g., a 1/3 frequency reuse, it is possible to transmit control information in an effective 4/12 reuse using only 3 frequencies. In Figure 3A, different kinds of control information or logical control channels have been indicated. In block B(0), broadcast information is transmitted on a Compact Broadcast Channel (C-BCCH) and, e.g., in block C(8), a Compact Common Control Channel (C-CCCH) is transmitted (e.g., paging messages).

The structure of the control channel is such that more blocks than those indicated can be allocated for control signaling. For example, if one more block is needed for CCCH, this can be allocated in physical block 2, on GSM frames 8-11. Allocation of 2-12 blocks is possible on a single timeslot. One broadcast information block and one common control block is always needed.

Further, to be able to find this control channel, a frequency correction burst and a synchronization burst is included in each 52 multiframe. A mobile will first search for the Frequency correction burst (located in GSM frame 25) and

it will know that following this, there will be a synchronization burst 26 GSM frames later, on the same timeslot. This synchronization burst helps the mobile station identify the base station and learn where in the multiframe structure it is.

Figure 2 illustrates an exemplary cell pattern that is formed by reuse of time groups and frequencies combined. Note that in Compact, only the control channels have to be transmitted in the higher reuse, utilizing the time groups. The traffic channels can still be transmitted in a 1/3 reuse.

As noted above, the transmission of control information in Compact is different than the control channel transmissions in present GSM systems. Present GSM systems have at least one carrier in each cell that transmits continuously with constant power (i.e., it transmits on all timeslots, even if there is no traffic allocated). In present GSM systems, this continuous transmission serves as a beacon in the system, enabling mobiles to find the control channel carrier, identify the cell and, e.g., make signal strength measurements for Mobile Assisted HandOver (MAHO) algorithms. For MAHO, a mobile station reports to the network how well it can hear neighbor cells and what signal strength it perceives. Then, based on those measurements, more reliable handovers are possible, as mobiles move between different cells.

In the Compact system, control channel signaling is only transmitted during one timeslot in a GSM frame. Signal strength measurements should be made on the control channel transmissions rather than on traffic channels, since traffic channels can be power controlled or not transmitted with a constant power. Thus, a mobile's measurement window must open during a timeslot when control is actually transmitted. To allow a mobile to measure on all of its neighbors in one and the same measurement position, another feature is introduced in the Compact scheme; that of timeslot rotation.

During one period, e.g., a 52 multiframe, the control messages transmitted in a cell belonging to time group 1, is transmitted on TS1, timeslot 1. During the

following, second period, e.g., the next 52 multiframe, the control transmissions from a timegroup 1 base station is transmitted on another timeslot, (e.g., timeslot 7, TS7). Now, during this second period, timeslot 1, TS1, carries control transmissions for, e.g.,timegroup 2 base stations, etc. By rotating the control timegroup allocation to different timeslots, all timegroups eventually transmit control in one certain timeslot (one of the odd numbered timeslots) and a mobile need not change its measurement window position (it can still measure on all the control channel transmissions from cells allocated different time groups).

Although the above described Compact scheme generally works well, applicants have recognized a deficiency in the Compact scheme with respect to frequency hopping. Frequency hopping is a technique to combat co-channel interference and fading. For example, frequency hopping can be used to limit the interference from other users, or rather, to prevent interference from one and the same user throughout the whole duration of a connection. Interference diversity is achieved. Frequency hopping also introduces frequency diversity which is advantageous, especially for slowly moving mobile stations, that otherwise may experience problems with, e.g., Rayleigh fading. Moreover, frequency hopping can also be used to eliminate the difficult task of frequency planning, which is of special importance in micro-cells. This can be achieved, e.g., if all of the cells in a system use the same frequencies, but each cell has a different hop sequence.

Frequency hopping is, of course, of marginal gain if there is only one frequency in a cell. Consequently, it is expected that initial deployment of Compact will not use frequency hopping. However, as the number of frequencies per cell increases, it will advantageous to permit frequency hopping. Thus, it is important that Compact standardization activities address frequency hopping from the beginning, since there will be no possibility to introduce it later.

Toward this end, the presently evolving Compact specification does address frequency hopping. For example, it has recently been proposed that

frequency hopping be permitted on timeslots TS 0, 2, 4 and 6, but not permitted on timeslots TS 1, 3, 5 and 7. A primary reason for this is that the odd timeslots are partially used to transmit control information as described above, and it would be impossible for an MS to initially read, e.g., broadcast information when the hopping pattern is not known. Since this information is transmitted on the broadcast channel, this cannot be a hopping channel.

Note, however, that such an approach presents a problem with respect to multi-slot mobile allocations (i.e., when a mobile is simultaneously allocated more than one timeslot in order to increase its data throughput over the air interface). Specifically, where frequency hopping is utilized, a multislot allocation requires that the different timeslots hop in an identical way, and it is thus not beneficial to have every second timeslot (i.e., every odd timeslot) be a "non-hopping" timeslot. Consequently, there is a need for improved methods and apparatus for performing frequency hopping in systems employing Compact frequency reuse.

Summary of the Invention

The present invention fulfills the above-described and other needs by providing techniques which permit frequency hopping on every timeslot in a wireless communications system employing the Compact scheme. As a result, the present invention allows frequency hopping to work even for multislot allocations within Compact-based systems.

An exemplary method for performing frequency hopping according to the invention can be applied, for example, in a wireless communication system in which at least one TDMA time slot is shared between at least two different types of logical channels. The exemplary method includes the steps of allocating a first type of logical channel to a single frequency on a shared time slot, and allocating a second type of logical channel to a frequency hopping sequence including at least two frequencies on the shared time slot.

On downlink timeslots, the first type of logical channel can include, for example, a broadcast channel, and the second type of logical channel can be, for example, a traffic data channel. Additionally, one of the two frequencies used in the frequency hopping sequence can be the same as the single frequency to which the first type of logical channel is allocated.

On uplink timeslots, logical channels of the second type can be used for all uplink transmissions. Alternatively, logical channels of the second type can include only a subset of available uplink logical channels, and logical channels of the first type can include at least one uplink logical channel.

The above-described and other features and advantages of the invention are explained in detail hereinafter with reference to the illustrative examples shown in the accompanying drawings. Those of ordinary skill in the art will appreciate that the described embodiments are provided for purposes of illustration and that numerous equivalent embodiments are contemplated herein.

Brief Description of the Drawings

Figure 1 depicts an exemplary wireless communications system in which the frequency hopping techniques of the invention can be implemented, the exemplary wireless system utilizing a 1/3 frequency reuse pattern.

Figure 2 depicts another exemplary wireless communications system in which the frequency hopping techniques of the invention can be implemented, the exemplary wireless system utilizing 1/3 frequency reuse pattern with an overlaid 1/4 timeslot reuse to provide an effective 4/12 time-frequency reuse.

Figure 3A illustrates an exemplary packet control channel downlink allocation pattern which can be utilized in the systems of Figures 1 and 2.

Figure 3B illustrates a packet control channel uplink allocation pattern which can be utilized in the systems of Figures 1 and 2.

Figure 4 depicts a number of different allocation scenarios in a frequency hopping Compact scheme according to the invention.

Figure 5 depicts an exemplary GPRS system in which frequency hopping Compact schemes according to the invention can be implemented.

Detailed Description of the Invention

The present invention is hereinafter described with reference to a GSM wireless communications system including the above described Compact scheme. In particular, the packet data mode of GSM Compact, i.e., GPRS or EGPRS Compact, is referred to. Those of skill in the art will appreciate, however, that the invention is readily applicable to other communications systems as well. For example, a Compact system with circuit switched connections, even though not exemplified, can make corresponding use of the present invention.

As described in the Background of the Invention section above, Compact is a deployment of a packet data system based on GPRS/GSM specifications on only 3 frequencies. It is however not limited to only 3 frequencies, and there can be more frequencies in a Compact system. The reason for specifying Compact is to provide, e.g., American operators with a way to introduce a packet data system which complies with the 1 MHZ maximum bandwidth requirement of the UWCC.

Briefly, Compact takes advantage of the benefits of a synchronized TDMA system, and generates a higher reuse for control transmissions than for traffic transmissions by utilizing a time reuse. Consequently, some of the frames on some of the timeslots will carry control in a high reuse (e.g., 4/12), and traffic will be transmitted on other (and parts of the same) timeslots in a lower reuse (e.g., a 1/3 reuse). See, for example, Figure 3A.

With respect to Figure 3A, note that in a GSM communication system, physical channels on which communication can occur are divided into timeslots on a radio frequency carrier. Each carrier frequency is divided into eight timeslots,

or eight physical channels. Eight consecutive timeslots form a GSM frame. The timeslots are labeled TS0-TS7, refering to both uplink and downlink timeslots.

As shown in Figure 3, four consecutive GSM frames form one radio block on each timeslot, TS0-TS7. There are different types of repetition cycles in the frame structure in GPRS and Compact. One such repetition is the 52 multiframe, containing 52 consecutive GSM frames. This is the repetition cycle used in GSM as soon as it is possible to allocate a traffic channel for user data and / or voice. In Compact, it is also the repetition cycle for all channels.

The 52 multiframe also includes, apart from 12 blocks for traffic or control, 2 idle GSM frames and 2 GSM frames used for Packet Timing Advance Control Channel Signalling (PTCCH), for a total of 4*12+2+2=52 GSM frames. The GSM frame structure and block allocation of logical channels is further described in ETSI TS 100 908 v.6.2.0 Digital Cellular Communication System (Phase 2+); "Multiplexing and multiple access on the radio path" (GSM 05.02 version 6.2.0 Release 1997), which is hereby incorporated by reference.

Figure 1 illustrates a typical 1/3 reuse pattern. Communication between an exemplary mobile 10 and an exemplary base station 12 is possible in each cell by allocating a frequency and a timeslot to a certain connection. The base stations can be situated in the center of a cell, in which case the antenna is transmitting in all directions. Alternatively, base station sites can serve, e.g., 3 different cells, as in the figure, in which case sector antennas are used.

A 1/3 reuse is a possible reuse pattern for data traffic. However, for control information or circuit switched communication, e.g., voice, a higher reuse is necessary as described above.

In Figure 2, a frequency repetition pattern f1-f2-f3 is illustrated together with an overlaid time group pattern tl-t2-t3-t4, where each time group identifies groups of base stations using different timeslots for control channel transmissions on the same frequency. This forms an effective 4/12 reuse for control channel

transmissions. As described above, a timeslot shift or rotation may also be introduced such that the time group does not use the same timeslot continuously.

Note that figure 3A depicts an exemplary allocation of control channels for the downlink transmissions in a Compact System. Base stations are allocated certain frequencies for control channels. Figure 3A, illustrates, for one such frequency, that a certain number of blocks on certain timeslots can be allocated for control channel transmission, whereas other blocks on the same timeslot can be used for traffic. There is flexibility in the number of control blocks to allocate.

In Figure 3A, one broadcast information transmission is allocated in the first block, in GSM frames 0-3, and three common control channel blocks are allocated in blocks 5, 8 and 11 on GSM frames, 21-24, 34-37 and 47-50, respectively. The other periods on the timeslots used for control can be used for Packet Data Traffic Channels or, e.g., Access Grant Channels.

In Figure 3A, a base station belonging to time group 1 can transmit control information on TS1, physical channel timeslot 1. A base station belonging to time group 2 can transmit control information on TS3, etc. Additionally, base stations in time group 1 will not transmit at all when base stations in other time groups transmit control information in order not to interfere with those transmissions. This is indicated in Figure 3A by shading in some of the blocks, e.g., TS3 and TS5 and TS7 in block B0 in time group 1.

In GSM frame 25, a frequency correction burst is included for each time group, and in GSM frame 51 a synchronisation burst for each time group is included. These bursts will enable mobiles to find the control channel and identify the current phase in the GSM frame repetition pattern.

Downlink blocks include a field in the header, intended for users that are allocated uplink resources in the cell. The message field is called USF, Uplink State Flag, and identifies the MS that can use the following blocks in the uplink. The USF value can take eight different values, 0-7, where each value can indicate

a certain MS. The allocation of a certain USF value is sent to an MS in an assignment message in the beginning of a packet connection setup.

Whenever an MS reads its assigned USF value in a downlink block in the timeslot it was allocated to, the MS can transmit either a single block or a sequence of four blocks on the same timeslot. The number of blocks allocated is controlled by a USF granularity field. The USF is sent in all downlink blocks.

The USF is also used to indicate allocation of an uplink control channel denoted random access channel, RA. A USF value (7) is reserved for this. Thus, if an MS reads a USF value of (7), this shall mean USF=FREE, or, the following blocks can be used for random access. This meaning of USF=(7) denoting a RA channel only applies on timeslots that are used for common control channel transmissions (i.e., PCCCH). U.S. Provisional Patent Application No. 60/145,262 describes additional techniques relating to use and operation of the USF and is incorporated herein in its entirety by reference.

Figure 3B illustrates a 52 multiframe for the uplink transmissions in a Compact system. In Figure 3B is illustrated that control timeslots TS1, TS3, TS5 and TS7 can carry both traffic (T) and random access channels (R).

Returning to Figure 3A, note that during some of the GSM frames, some of the timeslots cannot be allocated for traffic, because they are either used for control transmissions in serving a cell, or idle blocks are scheduled to provide a higher reuse for neighbor cells transmitting at coinciding instants (shaded blocks). Thus, at these GSM frames, it is only possible to allocate traffic in, e.g., TS 0, 2, 4 and 6. However, typically a complete timeslot is not allocated for control, and some frames actually allow allocating all TS for traffic.

As described in the Background of the Invention, this variation from frame to frame creates problems with respect to multislot allocation when frequency hopping is introduced. Specifically, conventional approaches to frequency hopping in a Compact system (e.g., not permitting hopping on the odd timeslots),

conflicts with the fact that a multislot MS allocation requires the different timeslots to hop in an identical way.

Advantageously, however, the present invention solves this dilemma by allowing frequency hopping on the timeslots where control channel transmissions are allocated, for those GSM frames where control is not transmitted. As a result, multislot allocations are possible, and every timeslot can include traffic to a certain MS, even in a frequency hopping allocation. According to the invention, the frequency hopping capability is no longer tied to a physical channel (e.g., a timeslot), but to a logical channel (e.g., the PDTCH or the Packet Associated Control Channel, or PACCH).

According to exemplary embodiments of the present invention, frequency hopping is applied in the downlink also on the timeslots that are shared with broadcast and common control channel transmissions. However, the blocks during which broadcast and common control is transmitted do not hop. These blocks and the frequency correction and synchronization bursts are always transmitted on the same frequency. This frequency is the control channel frequency of the cell, as earlier described. In the uplink, all the blocks hop, even those used for Common control (i.e., the Packet Random Access Channel, or PRACH). Alternatively, the uplink hopping pattern can follow the hopping pattern of the downlink, i.e., such that some blocks, for example the Packet Random access blocks, are transmitted on the same frequency.

In Figure 4, an exemplary allocation is illustrated. Herein, three users are allocated with frequency hopping. Specifically, two users (MSM1 and MSM2) are allocated a two-slot allocation, and one user (MSS3) is allocated a single slot allocation. The frequencies used for hopping in this scenario are f1, f2, f3 and f4. It should be appreciated that more frequencies can be used, and the hopping can also come in any order, for example cyclic or pseudorandom order. For simplicity, and for explaining the principles, only four frequencies are used, and

they are arranged in a f1-f4 cycle. In the figure, Bf1 indicates Broadcast transmitted on frequency 1, and Cf1 indicates Common control transmitted on frequency 1.

On TS0 and TS1, MSM2 is allocated two slots in a frequency hopping pattern. During the block where control is sent (GSM frame 0-3), nothing is transmitted to MSM2 on TS1, however MSM2 can still receive on TS0. During the next block period (GSM frame 4-7), MSM2 receives on both TS0 and TS1 in a hopping pattern on f1-f4.

On TS4 and TS5, MSM1 is not receiving anything on GSM frame 0-3. Instead, there is a single slot allocated user multiplexed there, i.e. MSS3. However, as soon as the two adjacent timeslots are both available for traffic, MSM1 can receive on both timeslots in a frequency hopping allocation, as shown.

According to one embodiment of the invention, an MS is always aware of when control is transmitted in the cell, or when the base station is silent because control is transmitted in another cell in the same cluster. Then, an MS occupied in (frequency hopping) transfer need not listen during those blocks, since no frequency hopping applies then, and nothing is transmitted to that particular MS.

Note that not having to listen for certain blocks is actually an advantage, since this leaves more time to make measurements on neighboring cell transmissions, which sometimes is difficult for an MS active in multislot allocations (especially if the MS is allocated a large number of slots, e.g., 6 timeslots).

According to another aspect of the present invention, a technique for handling of the USF is provided in connection with the above described frequency hopping Compact schemes. Ideally, an MS in idle mode, only listening to the broadcast and common control blocks, does not need to know or be concerned wiht the frequency hopping pattern, since these blocks are transmitted on the same carrier. However, an MS that aims to perform a random access attempt must

listen to the USF, which signals the MS as to which blocks random access is allowed (i.e., where Packet Random Access Channel, or PRACH, occurs). These indications can also be provided in a frequency hopping traffic block.

As stated earlier, one value of the USF indicates that the following uplink block is a random access block. To read the USF in each block on a certain control timeslot, the MS must first know the hopping sequence. The MS is informed about the frequency hopping by reading the broadcast information transmitted on the control channel carrier in the cell, which does not apply frequency hopping.

In an alternate embodiment, it is also possible to allocate fixed uplink blocks in a multiframe pattern, where PRACH always occurs. Then, an MS in idle mode need not bother at all about the hopping on the control channel timeslot, to find where PRACH is allocated.

In yet another embodiment of the present invention, it is also possible to apply frequency hopping to the common control channel blocks, and just have a fixed frequency for the broadcast blocks, frequency correction and synchronization bursts. Here the same approach as described above is generally applicable. However, here an MS in idle mode must also follow the hopping pattern in the downlink to monitor the common control channel blocks.

Generally, the present invention provides techniques which permit frequency hopping on every timeslot in a wireless communication systems employing, e.g., a Compact scheme. It does so by connecting the frequency hopping allocation to a set of logical channels (e.g., PDTCH, PACCH, PRACH) rather that to a set of physical channels. The invention thus overcomes the difficulties introduced in mixing hopping and non-hopping transmissions on the same physical carrier. Thus, the invention makes it possible for efficient frequency hopping multislot allocations via a Compact control channel carrier.

Figure 5 depicts an exemplary GPRS system in which the above described embodiments of the invention can be implemented. In the figure, a number of system nodes are shown. It will be appreciated that, in other exemplary systems, additional nodes can be included and/or some nodes shown can be omitted. As shown, a mobile station, or MS, 92 communicates with a base station 93. Of course, more base stations and MSs are usually present in packet data systems.

As shown, the base station 93 is connected to a Base Station Control node, or BSC 94, which in turn is connected to a Serving GPRS Support Node, or SGSN 95, serving one or several BSCs. One GPRS support node is a Gateway GPRS Support Node, or GGSN 96 connected to, e.g., other networks (not shown in the figure).

In Figure 5, a scheduler 97 is illustrated. While it is shown located in the BSC, it can alternatively be located in other network nodes as well, e.g., the base station or the SGSN. Scheduling functionality can also be split between different nodes. However, for simplicity, it is shown located in one node in Figure 5. The scheduler 97 performs the scheduling of blocks to use for different channels, e.g., for different logical channels, such as Common control channels and traffic channels.

In the base station 93, an RF modulator 98 is included. A transmitting frequency synthesizer 99 in the base station generates a transmitter carrier frequency in accordance with certain commands. If frequency hopping is implemented, the commands indicate which frequency to be used for each GSM frame and timeslot in accordance with the correct hopping information. One or several microprocessors and data memories (not shown) are used in the calculation and storage of information about the hopping sequences and calculations of the correct frequency at the correct GSM frame and timeslot.

In accordance with one aspect of the present invention, the transmitting frequency synthesizer 99 feeds the RF modulator 98 with frequencies

corresponding to the rules applied for allocation of different types of logical channels onto physical channels, considering frequency hopping rules as described above. For example, as illustrated in figure 4, for transmission to MSM2, during GSM frame 0-3, the frequency synthesizer feeds the frequency f1 to the RF modulator during GSM frame 0. Frequency f1 is used for transmitting to MSM2 during TS0, and during TS1 no transmissions to MSM2 occur. During GSM frame 1, frequency f2 is used for transmission to MSM2 during TS0, and during TS1 no transmissions to MSM2 occur, and so forth.

The transmission in GSM frames 0-3 on TS1 is also ruled by the frequency synthesizer 99 and RF modulator 98 such that the same frequency f1 is used during this period. During the following period on TS1, the synthesizer 99 feeds the RF modulator with frequencies f1-f4, similarly as was done for the TS0 during GSM frames 0-3.

The principles for a receiving unit in the base station are the same as those explained for a transmitting unit. Thus, a description of the receiving unit in the base station is omitted here for sake of brevity.

It will be appreciated by those skilled in the art that the above is an exemplary view of a system implementation, and that there are many other ways of realizing the frequency hopping in many different types of system, for which the present invention is equally applicable. It should also be realized to those skilled in the art, that even though it is not shown in Figure 5, the mobile station 92 includes a similar setup for generating and receiving signals to enable the disclosed frequency hopping.

Those skilled in the art will appreciate that the present invention is not limited to the specific exemplary embodiments which have been described herein for purposes of illustration and that numerous alternative embodiments are also contemplated. The scope of the invention is therefore defined by the claims

appended hereto, rather than the foregoing description, and all equivalents which are consistent with the meaning of the claims are intended to be embraced therein.

<u>Claims</u>:

1. A method for performing frequency hopping in a wireless communication system in which at least one Time Division Multiple Access (TDMA) time slot is shared between at least two different types of logical channels, comprising the steps of:

allocating a first type of logical channel to a single frequency on a shared time slot; and

allocating a second type of logical channel to a frequency hopping sequence including at least two frequencies on the shared time slot.

2. The method of claim 1, wherein the first type of logical channel includes a broadcast channel.

3. The method of claim 1, wherein one of the two frequencies used in the frequency hopping sequence is the same as the single frequency to which the first type of logical channel is allocated.

4. The method of claim 1, wherein the second type of logical channel is a traffic data channel.

5. The method of claim 1, wherein the wireless communication system is a packet data communication system.

6. The method of claim 5, wherein the packet data communication system is based on GPRS or EGPRS.

7. The method of claim 1, wherein the wireless communication system is a packet data communication system based on a Compact scheme employing both a frequency and time reuse, and wherein logical channels of the first type are allocated in a timeslot rotating fashion.

8. The method of claim 1, wherein logical channels of the second type are used for all uplink transmissions.

9. The method of claim 1, wherein logical channels of the second type include only a subset of available uplink logical channels, and wherein logical channels of the first type include at least one uplink logical channel.

10. The method of claim 5, wherein the second type of logical channels are transmitted on at least two frequencies, and wherein the at least two frequencies are selected in a pseudorandom fashion between TDMA frames.

11. The method of claim 5, wherein the second type of logical channels are transmitted on at least two frequencies, and wherein the at least two frequencies are selected in a cyclic fashion between TDMA frames.

12. The method of claim 1, wherein a Random Access channel allocation in an uplink is allocated by an indication in a preceding downlink block, and wherein the preceding downlink block is a transmission of a logical channel of the second type.

13. The method of claim 6, wherein a Random Access channel allocation in an uplink is fixed allocated such that it occurs in fixed blocks in each of a succession of TDMA 52 multiframes.

14. A wireless communications system in which at least one Time Division Multiple Access (TDMA) time slot is shared between at least two different types of logical channels, comprising:

a base station configured to allocate a first type of logical channel to a single frequency on a shared time slot and to allocate a second type of logical channel to a frequency hopping sequence including at least two frequencies on the shared time slot.

15. The system of claim 14, wherein the first type of logical channel includes a broadcast channel.

16. The system of claim 14, wherein one of the two frequencies used in the frequency hopping sequence is the same as the single frequency to which the first type of logical channel is allocated.

17. The system of claim 14, wherein the second type of logical channel is a traffic data channel.

18. The system of claim 14, wherein the wireless communication system is a packet data communication system based on a Compact scheme employing both a frequency and time reuse, and wherein logical channels of the first type are allocated in a timeslot rotating fashion.

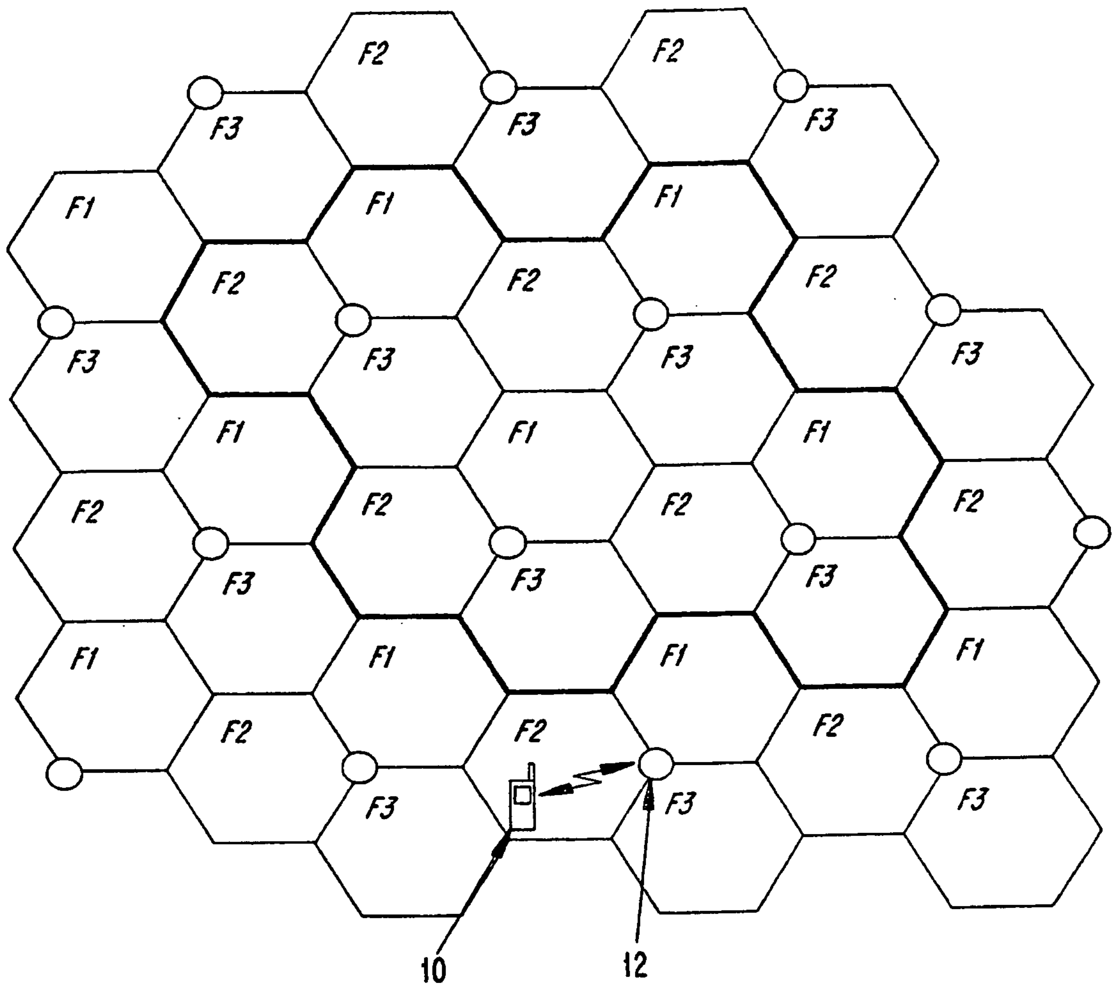
19. A wireless communications system in which at least one Time Division Multiple Access (TDMA) time slot is shared between at least two different types of logical channels, comprising:

a mobile station configured to allocate a first type of logical channel to a single frequency on a shared time slot and to allocate a second type of logical

channel to a frequency hopping sequence including at least two frequencies on the shared time slot.

20. The system of claim 19, wherein logical channels of the second type are used for all uplink transmissions.

21. The system of claim 19, wherein logical channels of the second type include only a subset of available uplink logical channels, and wherein logical channels of the first type include at least one uplink logical channel.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F2
F3
F3
F3
F1
F1
F1
F2
F2
F2
F3
F3
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F1
F1
F2
F2
F2
F2
F3
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F3
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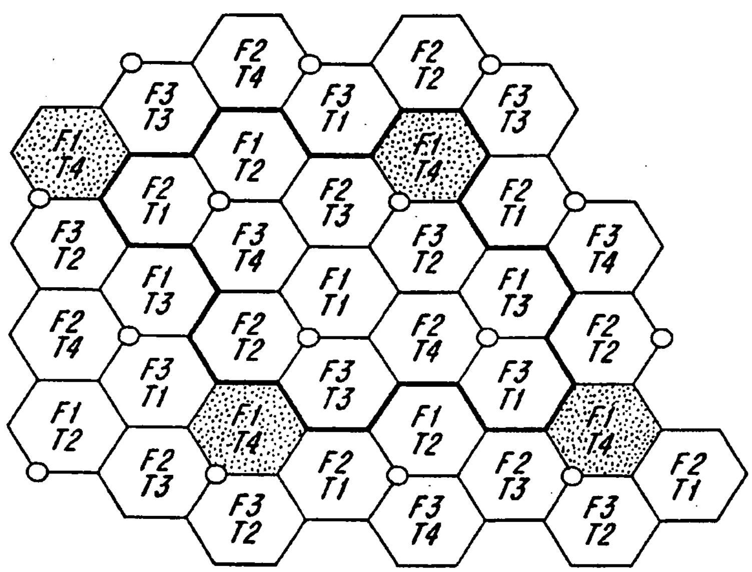
F3
10
12

Fig. 1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F2 T2
F3 T3
F3 T1
F3 T3
F1 T4
F1 T2
F1 T4
F2 T1
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F3 T2
F3 T4
F3 T2
F3 T4
F1 T3
F1 T1
F1 T3
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F3 T1
F1 T2
F1 T4
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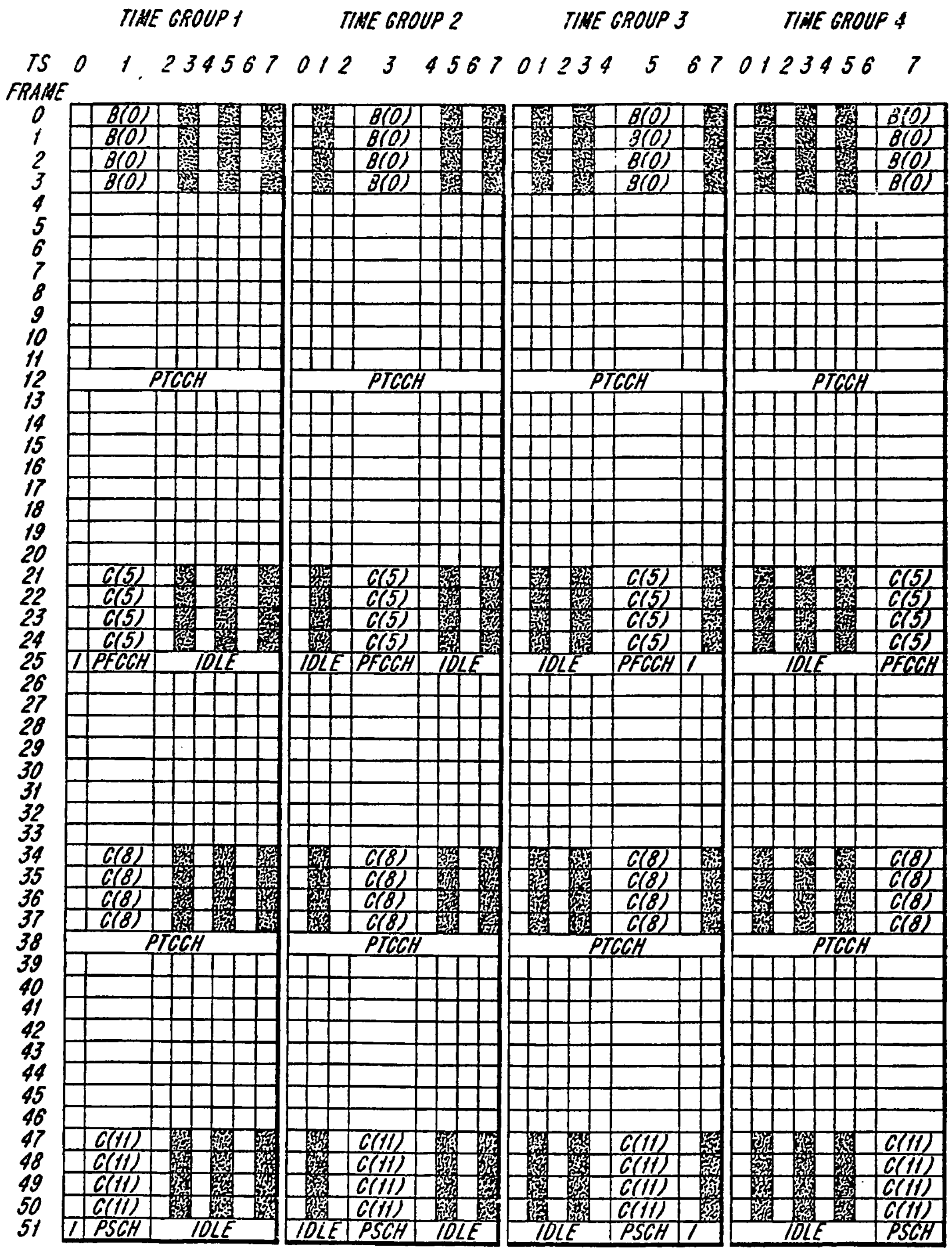
F3 T4
F3 T2

Fig. 2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TIME GROUP 2
TIME GROUP 3
TIME GROUP 4
TS 0 1 2 3 4 5 6 7 0 1 2 3 4 5 6 7 0 1 2 3 4 5 6 7 0 1 2 3 4 5 6 7
FRAME
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51
B(0)
PTCCH
C(5)
I PFCCH IDLE
IDLE PFCCH IDLE
IDLE PFCCH I
IDLE PFCCH
C(8)
C(11)
I PSCH IDLE
IDLE PSCH IDLE
IDLE PSCH I
IDLE PSCH

Fig. 3A

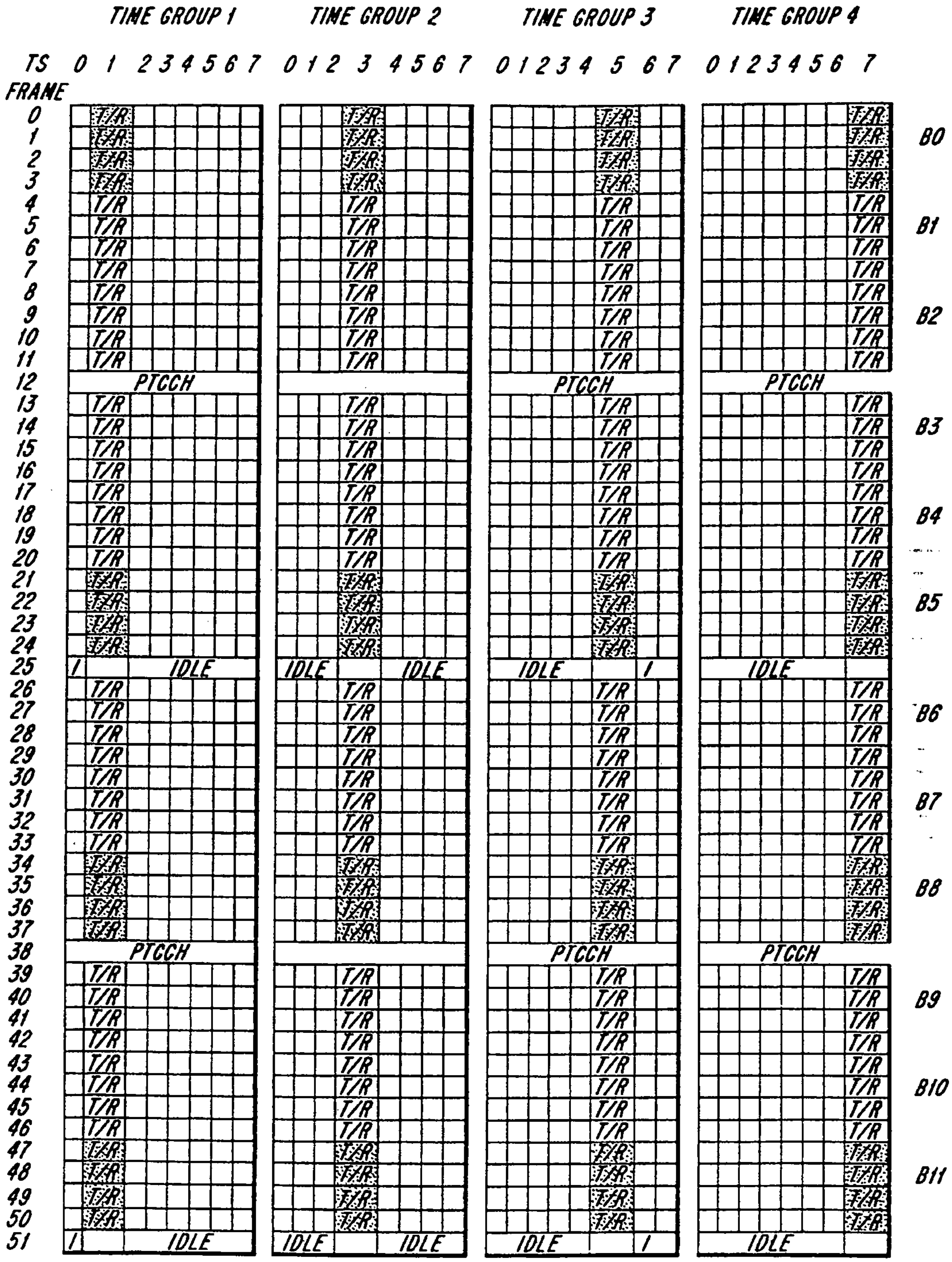
TIME GROUP 1
TIME GROUP 2
TIME GROUP 3
TIME GROUP 4
TS 0 1 2 3 4 5 6 7 0 1 2 3 4 5 6 7 0 1 2 3 4 5 6 7 0 1 2 3 4 5 6 7
FRAME
T/R
PTCCH
IDLE
B0
B1
B2
B3
B4
B5
B6
B7
B8
B9
B10
B11

Fig. 3B

FRAME NO	TS0	TS1	TS2	TS3	TS4	TS5	TS6	TS7
0	f1(MSM2)	Bfl			f1(MSS3)			
1	f2(MSM2)	Bfl			f2(MSS3)			
2	f3(MSM2)	Bfl			f3(MSS3)			
3	f4(MSM2)	Bfl			f4(MSS3)			
4	f1(MSM2)	f1(MSM2)			f1(MSM1)	f1(MSM1)		
5	f2(MSM2)	f2(MSM2)			f2(MSM1)	f2(MSM1)		
6	f3(MSM2)	f3(MSM2)			f3(MSM1)	f3(MSM1)		
7	f4(MSM2)	f4(MSM2)			f4(MSM1)	f4(MSM1)		
8	f1(MSM2)	f1(MSM2)			f1(MSM1)	f1(MSM1)		
9	f2(MSM2)	f2(MSM2)			f2(MSM1)	f2(MSM1)		
10	f3(MSM2)	f3(MSM2)			f3(MSM1)	f3(MSM1)		
11	f4(MSM2)	f4(MSM2)			f4(MSM1)	f4(MSM1)		
12								
13								
14								
15								
16								
17								
18								
19								
20								
21		Cfl						
22		Cfl						
23		Cfl						
24		Cfl						
25		SCH		SCH		SCH		SCH
26								
27								
28								
29								
30								
31								
32								
33		Cfl						
34		Cfl						
35		Cfl						
36		Cfl						
37								
38								
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41								
42								
43								
44								
45								
46								
47		Cfl						
48		Cfl						
49		Cfl						
50		Cfl						
51		FCH		FCH		FCH		FCH

Fig. 4

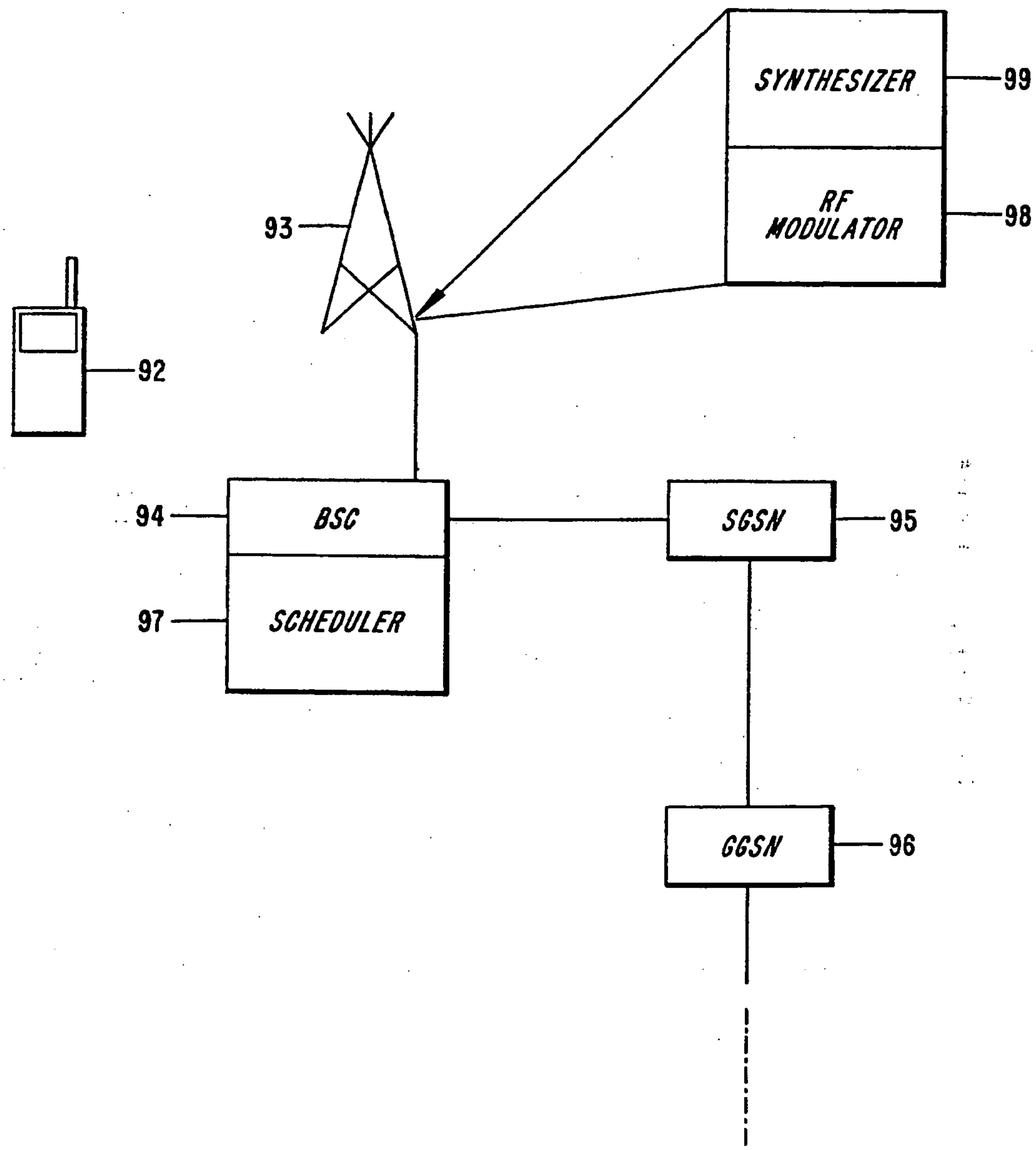
SYNTHESIZER
99
RF
MODULATOR
98
93
92
BSC
94
SCHEDULER
97
SGSN
95
GGSN
96

Fig. 5

INTERNATIONAL SEARCH REPORT

Inte onal Application No
PCT/SE 00/02112

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04B7/26 H04Q7/38

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04B H04Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	NASLUND J ET AL: "AN EVOLUTION OF GSM" PROCEEDINGS OF THE VEHICULAR TECHNOLOGY CONFERENCE,US,NEW YORK, IEEE, vol. CONF. 44, 1994, pages 348-352, XP000496693	1,2,4,5, 10,14, 15,17,19
Y	figures 1,3,5	6
A	* paragraphs 3,5,6 *	6-8,18, 20

	-/--	

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
11 January 2001	18/01/2001

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Sorrentino, A

1

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
X	WO 96 07284 A (GITLITS MAXIM VLADIMIROVICH ;TELSTRA CORP LTD (AU)) 7 March 1996 (1996-03-07)	1,2,4,8, 14,15, 17,19,20
A	page 9, line 11 - line 15	5-7, 9-12,16, 18,21
	page 11, line 3 - line 5 page 11, line 17 -page 12, line 2 page 12, line 31 -page 13, line 18 page 14, line 5 - line 12 figures 10,13 ---	
Y	OLOFSSON H; FURUSKAR A: "Aspects of introducing EDGE in exsisting gsm networks" IEEE 1998 INTERNATIONAL CONFERENCE ON UNIVERSAL PERSONAL COMMUNICATIONS.CONFERENCE PROCEEDINGS, 'Online! vol. 1, pages 421-426, XP002140616 ISBN: 0-7803-5106-1 Retrieved from the Internet: <URL:http://iel.ihs.com> 'retrieved on 2000-06-20!	6
A	page 423, paragraph B	1,7,14, 18,19
	figure 2 ---	
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A	US 5 844 894 A (DENT PAUL W) 1 December 1998 (1998-12-01) claims 1,6 -----	1,14,19

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

Inte   onal Application No
PCT/SE 00/02112

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
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GB 2328583	A	24-02-1999	AU	8979398 A	16-03-1999
			WO	9911084 A	04-03-1999
US 5844894	A	01-12-1998	AU	1971597 A	16-09-1997
			WO	9732441 A	04-09-1997